# Quark and Lepton Compositeness, Searches for

The latest unpublished results are described in the "Quark and Lepton Compositeness" review.

A REVIEW GOES HERE – Check our WWW List of Reviews

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#### SCALE LIMITS for Contact Interactions: $\Lambda(eeee)$

Limits are for  $\Lambda_{II}^{\pm}$  only. For other cases, see each reference.

$\Lambda_{LL}^-({\sf TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
>10.3	95	<sup>1</sup> BOURILKOV	01	RVUE	E <sub>cm</sub> = 192–208 GeV
e do not us	e the fo	ollowing data for ave	rages	, fits, lim	nits, etc. • • •
>7.0	95	<sup>2</sup> SCHAEL	07A	ALEP	$E_{\rm cm} = 189 - 209 \; {\rm GeV}$
>6.8	95	ABDALLAH	<b>06</b> C	DLPH	$E_{\rm cm} = 130-207  {\rm GeV}$
>6.1	95	<sup>3</sup> ABBIENDI	<b>04</b> G	OPAL	$E_{\rm cm} = 130-207  {\rm GeV}$
>5.4	95	ABREU	<b>00</b> S	DLPH	$E_{\rm cm} = 183 - 189  \text{GeV}$
>4.9	95	ACCIARRI	<b>00</b> P	L3	$E_{\rm cm} = 130 - 189 \; {\rm GeV}$
	>10.3 e do not use >7.0 >6.8 >6.1 >5.4			$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

 $^{1}\mathrm{A}$  combined analysis of the data from ALEPH, DELPHI, L3, and OPAL.

NODE=S054CTE;LINKAGE=BT NODE=S054CTE;LINKAGE=SE NODE=S054CTE;LINKAGE=AB

## SCALE LIMITS for Contact Interactions: $\Lambda(ee\mu\mu)$

Limits are for  $\Lambda_{LL}^{\pm}$  only. For other cases, see each reference.

$\Lambda_{LL}^+(\text{TeV})$	$\Lambda_{LL}^-({\sf TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
>6.6	>9.5	95	<sup>4</sup> SCHAEL	07A	ALEP	E <sub>cm</sub> = 189–209 GeV
> 8.5	>3.8	95	ACCIARRI	<b>00</b> P	L3	$E_{\rm cm} = 130 - 189 \; {\rm GeV}$

NODE=S054CTM

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NODE=S054CNT

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 $<sup>^2</sup>$  SCHAEL 07A limits are from  ${\it R_c},~{\it Q}_{FB}^{depl}$  , and hadronic cross section measurements.

<sup>&</sup>lt;sup>3</sup> ABBIENDI 04G limits are from  $e^+e^- \rightarrow e^+e^-$  cross section at  $\sqrt{s}=$  130–207 GeV.

NODE=S054CTT

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• • • We do not use the following data for averages, fits, limits, etc. • • •

>7.3	>7.6	95				$E_{\rm cm} = 130 - 207 \; {\rm GeV}$
>8.1	>7.3	95	<sup>5</sup> ABBIENDI	04G	OPAL	$E_{\rm cm} = 130-207 \; {\rm GeV}$
>6.6	>6.3	95	ABREU			$E_{\rm cm} = 183 - 189 \; {\rm GeV}$

 $<sup>^4</sup>$  SCHAEL 07A limits are from  $R_c,\ Q_{FB}^{depl},$  and hadronic cross section measurements.

NODE=S054CTM;LINKAGE=SE NODE=S054CTM;LINKAGE=AB

#### SCALE LIMITS for Contact Interactions: $\Lambda(ee\tau\tau)$

Limits are for  $\Lambda_{LL}^{\pm}$  only. For other cases, see each reference.

$\Lambda_{LL}^+$ (TeV)	$\Lambda_{LL}^{-}(\text{TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
>7.9	>5.8	95	<sup>6</sup> SCHAEL	07A	ALEP	$E_{\rm cm} = 189 - 209 \; {\rm GeV}$
>7.9	>4.6	95	ABDALLAH	<b>06</b> C	DLPH	$E_{\rm cm} = 130-207 \; {\rm GeV}$
>4.9	>7.2	95	<sup>7</sup> ABBIENDI	04G	OPAL	$E_{\rm cm} = 130-207 \; {\rm GeV}$
• • • We	e do not us	e the follo	owing data for ave	erages	, fits, lim	nits, etc. • • •
>5.2	>5.4	95	ABREU	<b>00</b> S	DLPH	$E_{\rm cm} = 183 - 189 \; {\rm GeV}$
>5.4	>4.7	95	ACCIARRI			$E_{\rm cm} = 130 - 189  {\rm GeV}$
6			denl			<del></del>

 $<sup>^{6}</sup>$  SCHAEL 07A limits are from  $R_c$ ,  $Q_{FB}^{aept}$ , and hadronic cross section measurements.

NODE=S054CTT;LINKAGE=SE NODE=S054CTT;LINKAGE=AB

## SCALE LIMITS for Contact Interactions: $\Lambda(\ell\ell\ell\ell)$

Lepton universality assumed. Limits are for  $\Lambda_{LL}^{\pm}$  only. For other cases, see each

$\Lambda_{LL}^+$ (TeV)	$\Lambda_{LL}^{-}(\text{TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
>7.9	> 10.3	95	8 SCHAEL	07A	ALEP	E <sub>cm</sub> = 189–209 GeV
>9.1	>8.2	95	ABDALLAH	06C	DLPH	$E_{\rm cm} = 130-207  {\rm GeV}$
• • • We	do not use	e the fo	ollowing data for ave	rages,	fits, lim	nits, etc. • • •
>7.7	>9.5	95	9 ABBIENDI			$E_{\rm cm} = 130 – 207 \; {\rm GeV}$
>9.0	>5.2	95	<sup>10</sup> BABICH ACCIARRI		RVUE L3	E <sub>cm</sub> = 130–189 GeV

NODE=S054CTL

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NODE=S054CTL

# SCALE LIMITS for Contact Interactions: $\Lambda(eeqq)$

Limits are for  $\Lambda_{LL}^{\pm}$  only. For other cases, see each reference.

$\Lambda_{LL}^+({\sf TeV})$	$\Lambda_{LL}^-({\sf TeV})$	CL%	DOCUMENT ID		TECN	COMMENT
> 9.5	>12.1	95	11 AAD	13E	ATLS	(eeqq)
> <b>10.1</b>	>9.4	95	<sup>12</sup> AAD	<b>12</b> AB	ATLS	(eeqq)
> 8.4	>10.2	95	<sup>13</sup> ABDALLAH	09	DLPH	(eebb)
> 9.4	>5.6	95	<sup>14</sup> SCHAEL	07A	ALEP	(eecc)
> 9.4	>4.9	95	<sup>13</sup> SCHAEL	07A	ALEP	(eebb)
>23.3	>12.5	95	<sup>15</sup> CHEUNG	<b>01</b> B	RVUE	(eeuu)
>11.1	>26.4	95	<sup>15</sup> CHEUNG	<b>01</b> B	RVUE	(eedd)
• • • We	do not use	the fo	ollowing data for ave	erages	, fits, lin	nits, etc. • • •
> 4.2	>4.0	95	<sup>16</sup> AARON	<b>11</b> C	H1	(eeqq)
> 3.8	>3.8	95	<sup>17</sup> ABDALLAH	11	DLPH	(eetc)
>12.9	>7.2	95	<sup>18</sup> SCHAEL	07A	ALEP	(eeqq)

<sup>95</sup>  $^{19}$  ABULENCIA 06L CDF (eeqq) $^{11}$  AAD 13E limis are from  $e^+e^-$  mass distribution in pp collisions at  $E_{\rm cm}=7$  TeV.

NODE=S054CTL;LINKAGE=SE NODE=S054CTL;LINKAGE=AB NODE=S054CTL;LINKAGE=HB

## NODE=S054CTH

NODE=S054CTH NODE=S054CTH;CHECK LIMITS

OCCUR=2

OCCUR=2

OCCUR=3

NODE=S054CTH;LINKAGE=I NODE=S054CTH;LINKAGE=G NODE=S054CTH;LINKAGE=AL NODE=S054CTH;LINKAGE=SE NODE=S054CTH;LINKAGE=BC

NODE=S054CTH;LINKAGE=RO NODE=S054CTH;LINKAGE=AA

NODE=S054CTH;LINKAGE=CE

<sup>&</sup>lt;sup>5</sup> ABBIENDI 04G limits are from  $e^+e^- \rightarrow \mu\mu$  cross section at  $\sqrt{s}=130$ –207 GeV.

<sup>&</sup>lt;sup>7</sup> ABBIENDI 04G limits are from  $e^+e^- 
ightarrow au au$  cross section at  $\sqrt{s}=$  130–207 GeV.

 $<sup>^8</sup>$  SCHAEL 07A limits are from  $R_c,~Q_{FB}^{depl}$ , and hadronic cross section measurements.  $^9$  ABBIENDI 04G limits are from  $e^+e^-\to \ell^+\ell^-$  cross section at  $\sqrt{s}=130$ –207 GeV.  $^{10}$  BABICH 03 obtain a bound  $-0.175~{\rm TeV}^{-2}<1/\Lambda_{LL}^2<0.095~{\rm TeV}^{-2}$  (95%CL) in a model independent analysis allowing all of  $\Lambda_{LL},~\Lambda_{LR},~\Lambda_{RL},~\Lambda_{RR}$  to coexist.

 $<sup>^{12}</sup>$  AAD 12AB limis are from  $e^+e^-$  mass distribution in pp collisions at  $E_{\rm cm}=7$  TeV.

 $<sup>^{13}</sup>$  ABDALLAH 09 and SCHAEL 07A limits are from  $R_b$ ,  $A_{FB}^b$ 

 $<sup>^{14}</sup>$  SCHAEL 07A limits are from  $R_c,\,Q_{FB}^{depl}$  , and hadronic cross section measurements. 15 CHEUNG 01B is an update of BARGER 98E.

<sup>&</sup>lt;sup>16</sup> AARON 11C limits are from  $Q^2$  spectrum measurements of  $e^{\pm} p \rightarrow e^{\pm} X$ . <sup>17</sup> ABDALLAH 11 limit is from  $e^+ e^- \rightarrow t \overline{c}$  cross section.  $\Lambda_{LL} = \Lambda_{LR} = \Lambda_{RL} = \Lambda_{RR}$ is assumed.

18 SCHAEL 07A limit assumes quark flavor universality of the contact interactions.

NODE=S054CTS NODE=S054CTS

NODE=S054CTH;LINKAGE=AI

#### SCALE LIMITS for Contact Interactions: $\Lambda(\mu \mu q q)$

$\Lambda_{LL}^+$ (TeV)	$\Lambda_{LL}^{-}(\text{TeV})$	CL%	DOCUMENT ID		TECN	COMMENT	
>9.6	>12.9	95	<sup>20</sup> AAD			$(\mu \mu q q)$ (isosinglet)	
>9.5	> 13.1	95	<sup>21</sup> CHATRCHYAN	<b>l</b> 13K	CMS	$(\mu \mu q q)$ (isosinglet)	
• • • We	do not use	the follo	owing data for aver	ages,	fits, limi	ts, etc. • • •	
>8.0	>7.0	95	<sup>22</sup> AAD	12AB	ATLS	$(\mu \mu q q)$ (isosinglet)	ı
>4.5	>4.9	95	<sup>23</sup> AAD	11E	ATLS	$(\mu \mu q q)$ (isosinglet)	
>2.9	>4.2	95	<sup>24</sup> ABE	97T	CDF	$(\mu \mu q q)$ (isosinglet)	
00							-

 $<sup>^{20}\,\</sup>mathrm{AAD}$  13E limis are from  $\mu^+\mu^-$  mass distribution in pp collisions at  $E_\mathrm{cm}=7$  TeV.

### NODE=S054CTS;LINKAGE=B NODE=S054CTS;LINKAGE=C

NODE=S054CTS;LINKAGE=A NODE=S054CTS;LINKAGE=AA NODE=S054CTS;LINKAGE=AT

## SCALE LIMITS for Contact Interactions: $\Lambda(\ell\nu\ell\nu)$

VALUE (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>3.10	90	<sup>25</sup> JODIDIO	86	SPEC	$\Lambda_{LR}^{\pm}( u_{\mu} u_{e}\mue)$
\\/- d+ +b-	fallanda.	- data fau allaua	£:+-	limaina a	

• • • We do not use the following data for averages, fits, limits, etc. • • •

>3.8	<sup>26</sup> DIAZCRUZ	94	RVUE $\Lambda_{LL}^+( au u_{ au}\mathrm{e} u_{e})$	
>8.1	<sup>26</sup> DIAZCRUZ	94	RVUE $\Lambda_{LL}^{-}(\tau \nu_{\tau} e \nu_{e})$	
>4.1	<sup>27</sup> DIAZCRUZ	94	RVUE $\Lambda_{LL}^+( au u_{ au}\mu u_{\mu})$	
>6.5	<sup>27</sup> DIAZCRUZ	94	RVUE $\Lambda_{II}^{-}(\tau \nu_{\tau} \mu \nu_{\mu})$	

 $^{25}$  JODIDIO 86 limit is from  $\mu^+ \to \overline{\nu}_\mu \, e^+ \, \nu_e.$  Chirality invariant interactions  $L = (g^2/\Lambda^2)$   $\left[\eta_{LL} \, (\overline{\nu}_\mu {}_L \gamma^\alpha \mu_L) \, (\overline{e}_L \gamma_\alpha \nu_{e\,L}) + \eta_{LR} \, (\overline{\nu}_\mu {}_L \gamma^\alpha \nu_{e\,L} \, (\overline{e}_R \gamma_\alpha \mu_R) \right]$  with  $g^2/4\pi = 1$  and  $(\eta_{LL}.\eta_{LR}) = (0,\pm 1)$  are taken. No limits are given for  $\Lambda^\pm_{LL}$  with  $(\eta_{LL}.\eta_{LR}) = (\pm 1,0).$  For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text.

<sup>26</sup> DIAZCRUZ 94 limits are from  $\Gamma(\tau \to e \nu \nu)$  and assume flavor-dependent contact interactions with  $\Lambda(\tau \nu_{\tau} e \nu_{e}) \ll \Lambda(\mu \nu_{\mu} e \nu_{e})$ .

#### NODE=S054CTN NODE=S054CTN

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NODE=S054CTN;LINKAGE=B

NODE=S054CTN;LINKAGE=A

NODE=S054CTN;LINKAGE=C

#### SCALE LIMITS for Contact Interactions: $\Lambda(e\nu qq)$

VALUE (TeV)	CL%	DOCUMENT ID		TECN
>2.81	95	28 AFFOLDER	011	CDF

<sup>&</sup>lt;sup>28</sup> AFFOLDER 001 bound is for a scalar interaction  $\overline{q}_R q_L \overline{\nu} e_L$ .

#### NODE=S054CQN NODE=S054CQN

NODE=S054CQN;LINKAGE=LI

# SCALE LIMITS for Contact Interactions: $\Lambda(qqqq)$

Limits are for  $\Lambda_{LL}^{\pm}$  with color-singlet isoscalar exchanges among  $u_L$ 's and  $d_L$ 's only, unless otherwise noted. See EICHTEN 84 for details.

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VALUE (TeV)	CL%_	DOCUMENT ID	TE	CN	COMMENT
>7.6 (CL = 95%)	[>5.6 Te	V (CL = 95%) OUR 2			
>7.6	95	<sup>29</sup> AAD 13	BD A7	ΓLS	$pp  o  ext{dijet angl.}$
>7.5	95	<sup>30</sup> CHATRCHYAN 12	z Ci	MS	$pp  ightarrow {\sf dijet}$ angl.; $arLambda_{LL}^+$
ullet $ullet$ We do not use	the follow	ing data for averages,	fits, li	mits,	etc. • • •
>3.4	95	31 AAD 11	L A	ΓLS	$ ho  ho  ightarrow {\sf dijet};  arLambda_{LL}^+$

>3.4	95			$ ho  ho  ightarrow {\sf dijet};  arLambda^+_{LL}$
>5.6	95	<sup>32</sup> KHACHATRY1	1F CMS	$p p  ightarrow {\sf dijet\ angl.};  arLambda_{LL}^+$
>4.0	95	<sup>33</sup> KHACHATRY1	OA CMS	$pp$ ; dijet centrality; $\Lambda_{LL}^{+}$
>2.96	95	<sup>34</sup> ABAZOV 0	9AE D0	$p\overline{p}  o dijet$ , angl. $\Lambda_{II}^+$

 $\mathsf{NODE}{=}\mathsf{S054CTQ}$ 

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NODE=S054CTQ

 $<sup>^{21}</sup>$  CHATRCHYAN 13K limis are from  $\mu^+\mu^-$  mass distribution in  $\it pp$  collisions at  $\it E_{\rm cm}=7$  TeV.

<sup>&</sup>lt;sup>22</sup>AAD 12AB limis are from  $\mu^+\mu^-$  mass distribution in pp collisions at  $E_{\rm cm}=7$  TeV.

 $<sup>^{23}</sup>$  AAD 11E limits are from  $\mu^+\mu^-$  mass distribution in  $\it pp$  collisions at  $\it E_{\rm cm}=7$  TeV.

<sup>&</sup>lt;sup>24</sup> ABE 97T limits are from  $\mu^+\mu^-$  mass distribution in  $\overline{p}p \to \mu^+\mu^-$ X at  $E_{\rm cm}$ =1.8 TeV.

<sup>&</sup>lt;sup>27</sup> DIAZCRUZ 94 limits are from  $\Gamma(\tau \to \mu\nu\nu)$  and assume flavor-dependent contact interactions with  $\Lambda(\tau\nu_{\tau}\mu\nu_{\mu}) \ll \Lambda(\mu\nu_{\mu}e\nu_{e})$ .

 $^{29}\,\mathrm{AAD}$  13D limit is from dijet angular distribution in pp collisions at  $E_\mathrm{cm}=7$  TeV. The constant prior in  $1/\Lambda^4$  is applied.

 $^{30}$  CHATRCHYAN 12Z limit is from dijet angular distribution in pp collisions at  $E_{\rm cm}=7$  TeV. They also obtain  $\Lambda_{LL}^->10.5$  TeV.

<sup>31</sup>AAD 11 limit is from dijet angular distribution and dijet centrality ratio in pp collisions at  $E_{\rm cm}=7$  TeV.

<sup>32</sup>KHACHATRYAN 11F limit is from dijet angular distribution in pp collisions at  $E_{\rm cm}=7$  TeV. They also obtain  $\Lambda_{LL}^->6.7$  TeV.

<sup>33</sup> The quoted limit is from dijet centrality ratio measurement in pp collisions at  $\sqrt{s}$ =7 TeV.

 $^{34}\,\text{ABAZOV}$  09AE also obtain  $\Lambda_{LL}^{-}~>$  2.96 TeV.

 ${\sf NODE}{=}{\sf S054CTQ;} {\sf LINKAGE}{=}{\sf L}$ 

NODE=S054CTQ;LINKAGE=M

NODE=S054CTQ;LINKAGE=AA

NODE=S054CTQ;LINKAGE=KA

NODE=S054CTQ;LINKAGE=KH

NODE=S054CTQ;LINKAGE=AB

#### SCALE LIMITS for Contact Interactions: $\Lambda(\nu \nu q q)$

Limits are for  $\Lambda_{LL}^{\pm}$  only. For other cases, see each reference.

 $^{35}\,\mathrm{MCFARLAND}$  98 assumed a flavor universal interaction. Neutrinos were mostly of muon type.

NODE=S054CTD

NODE=S054CTD NODE=S054CTD

NODE=S054CTD;LINKAGE=A

#### MASS LIMITS for Excited $e(e^*)$

Most  $e^+e^-$  experiments assume one-photon or Z exchange. The limits from some  $e^+e^-$  experiments which depend on  $\lambda$  have assumed transition couplings which are chirality violating  $(\eta_L=\eta_R)$ . However they can be interpreted as limits for chirality-conserving interactions after multiplying the coupling value  $\lambda$  by  $\sqrt{2}$ ; see Note.

Excited leptons have the same quantum numbers as other ortholeptons. See also the searches for ortholeptons in the "Searches for Heavy Leptons" . .

#### NODE=S054220

NODE=S054220

#### Limits for Excited e (e\*) from Pair Production

These limits are obtained from  $e^+e^- \to e^{*+}e^{*-}$  and thus rely only on the (electroweak) charge of  $e^*$ . Form factor effects are ignored unless noted. For the case of limits from Z decay, the  $e^*$  coupling is assumed to be of sequential type. Possible t channel contribution from transition magnetic coupling is neglected. All limits assume a dominant  $e^* \to e\gamma$  decay except the limits from  $\Gamma(Z)$ .

For limits prior to 1987, see our 1992 edition (Physical Review D45 S1 (1992)).

NODE=S054EXP NODE=S054EXP

NODE=S054EXP

 VALUE (GeV)
 CL%
 DOCUMENT ID
 TECN
 COMMENT

 >103.2
 95
 36 ABBIENDI
 02G
 OPAL
  $e^+e^- \rightarrow e^*e^*$  Homodoublet type

 • • • We do not use the following data for averages, fits, limits, etc. • • •

>102.8 95 <sup>37</sup> ACHARD 03B L3  $e^+e^- \rightarrow e^*e^*$  Homodoublet type

 $^{36}$  From  $e^+e^-$  collisions at  $\sqrt{s}=183$ –209 GeV. f=f' is assumed.

 $^{37}$  From  $e^+\,e^-$  collisions at  $\sqrt{s}=$  189–209 GeV. f=f' is assumed. ACHARD 03B also obtain limit for  $f=-f'\colon m_{e^*}>$  96.6 GeV.

NODE=S054EXP;LINKAGE=GN NODE=S054EXP;LINKAGE=CR

#### Limits for Excited e (e\*) from Single Production

These limits are from  $e^+e^- \to e^*e$ ,  $W \to e^*\nu$ , or  $ep \to e^*X$  and depend on transition magnetic coupling between e and  $e^*$ . All limits assume  $e^* \to e\gamma$  decay except as noted. Limits from LEP, UA2, and H1 are for chiral coupling, whereas all other limits are for nonchiral coupling,  $\eta_L = \eta_R = 1$ . In most papers, the limit is expressed in the form of an excluded region in the  $\lambda - m_{e^*}$  plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

 VALUE (GeV)
 CL%
 DOCUMENT ID
 TECN
 COMMENT

 > 1.870 × 10³ (CL = 95%)
 [>1.070 × 10³ GeV (CL = 95%) OUR 2012 BEST LIMIT]

 >1870
 95
 38 AAD
 12AZ ATLS  $pp \rightarrow e^{(*)}e^*X$ 

NODE=S054EXS NODE=S054EXS

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 $\bullet$   $\bullet$  We do not use the following data for averages, fits, limits, etc.  $\bullet$   $\bullet$ 

>1070	95	<sup>39</sup> CHATRCHYAI	N 11X	CMS	$pp \rightarrow ee^*X$
> 272	95	<sup>40</sup> AARON	08A	H1	$ep \rightarrow e^*X$
		<sup>41</sup> ABAZOV	08н	D0	$p\overline{p} \rightarrow e^*e$
> 209	95	<sup>42</sup> ACOSTA	<b>05</b> B	CDF	$p\overline{p} \rightarrow e^*X$
> 206	95	<sup>43</sup> ACHARD	<b>03</b> B	L3	$e^+e^- ightarrow~ee^*$
> 208	95	<sup>44</sup> ABBIENDI	02G	OPAL	$e^+e^- ightarrow~ee^*$
> 228	95	<sup>45</sup> CHEKANOV	<b>02</b> D	ZEUS	$ep \rightarrow e^*X$

<sup>38</sup> AAD 12AZ search for  $e^*$  production via four-fermion contact interaction in pp collisions with  $e^* \to e\gamma$  decay. The quoted limit assumes  $\Lambda = m_{e^*}$ . See their Fig. 8 for the exclusion plot in the mass-coupling plane.

<sup>39</sup> CHATRCHYAN 11X search for single  $e^*$  production in  $p\,p$  collisions with the decay  $e^* \to e\,\gamma$ .  $f=f'=\Lambda/m_{e^*}$  is assumed. See their Fig. 2 for the exclusion plot in the mass-coupling plane.

<sup>40</sup> AARON 08A search for single  $e^*$  production in ep collisions with the decays  $e^* \to e\gamma$ , eZ,  $\nu W$ . The quoted limit assumes  $f = f' = \Lambda/m_{e^*}$ . See their Fig. 3 and Fig. 4 for the exclusion plots in the mass-coupling plane.

<sup>41</sup> ABAZOV 08H search for single  $e^*$  production in  $p\overline{p}$  collisions with the decays  $e^* \rightarrow e\gamma$ . The  $e^*$  production is assumed to be described by an effective four-fermion interaction. See their Fig. 5 for the exclusion plot in the mass-coupling plane.

<sup>42</sup> ACOSTA 05B search for single  $e^*$  production in  $p\overline{p}$  collisions with the decays  $e^* \to e\gamma$ .  $f = f' = \Lambda/m_{e^*}$  is assumed for the  $e^*$  coupling. See their Fig.3 for the exclusion limit in the mass-coupling plane.

 $^{43}$  ACHARD 03B result is from  $e^+e^-$  collisions at  $\sqrt{s}=189$ –209 GeV. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

<sup>44</sup> ABBIENDI 02G result is from  $e^+e^-$  collisions at  $\sqrt{s}=183$ –209 GeV.  $f=f'=\Lambda/m_{e^*}$  is assumed for  $e^*$  coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.

<sup>45</sup>CHEKANOV 02D search for single  $e^*$  production in ep collisions with the decays  $e^* \rightarrow e\gamma$ , eZ,  $\nu W$ .  $f=f'=\Lambda/m_{e^*}$  is assumed for the  $e^*$  coupling. See their Fig. 5a for the exclusion plot in the mass-coupling plane.

## Limits for Excited e ( $e^*$ ) from $e^+e^- \rightarrow \gamma\gamma$

These limits are derived from indirect effects due to  $e^*$  exchange in the t channel and depend on transition magnetic coupling between e and  $e^*$ . All limits are for  $\lambda_{\gamma}=1$ . All limits except ABE 89J and ACHARD 02D are for nonchiral coupling with  $\eta_{L}=\eta_{R}=1$ . We choose the chiral coupling limit as the best limit and list it in the Summary Table.

For limits prior to 1987, see our 1992 edition (Physical Review D45 S1 (1992)).

VALUE (GeV)	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
>356	95	<sup>46</sup> ABDALLAH	04N	DLPH	$\sqrt{s}$ = 161–208 GeV
• • • We do not use	the following	ng data for average	s, fits,	limits, e	etc. • • •
>310	95	ACHARD	<b>02</b> D	L3	$\sqrt{s}$ = 192–209 GeV

 $^{46}$  ABDALLAH 04N also obtain a limit on the excited electron mass with ee\* chiral coupling,  $m_{e^*}>$  295 GeV at 95% CL.

#### Indirect Limits for Excited e (e\*)

These limits make use of loop effects involving  $e^*$  and are therefore subject to theoretical uncertainty.

retical uncertainty.				
VALUE (GeV)	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the fe	ollowing data for averages	, fits, lim	its, etc. • • •	
	47			

$$^{47}$$
 DORENBOS... 89 CHRM  $\overline{\nu}_{\mu}\,e \rightarrow \,\overline{\nu}_{\mu}\,e,\,\nu_{\mu}\,e \rightarrow \,\nu_{\mu}\,e$   $^{48}$  GRIFOLS 86 THEO  $\nu_{\mu}\,e \rightarrow \,\nu_{\mu}\,e$   $^{49}$  RENARD 82 THEO  $g{-}2$  of electron

 $^{47}$  DORENBOSCH 89 obtain the limit  $\lambda_{\gamma}^2 \Lambda_{\rm cut}^2/m_{e^*}^2 < 2.6$  (95% CL), where  $\Lambda_{\rm cut}$  is the cutoff scale, based on the one-loop calculation by GRIFOLS 86. If one assumes that  $\Lambda_{\rm cut}=1$  TeV and  $\lambda_{\gamma}=1$ , one obtains  $m_{e^*}>620$  GeV. However, one generally expects  $\lambda_{\gamma} \approx m_{e^*}/\Lambda_{\rm cut}$  in composite models.

 $^{48}\,\text{GRIFOLS}$  86 uses  $\nu_{\mu}\,e \to \nu_{\mu}\,e$  and  $\overline{\nu}_{\mu}\,e \to \overline{\nu}_{\mu}\,e$  data from CHARM Collaboration to derive mass limits which depend on the scale of compositeness.

 $^{49}$  RENARD 82 derived from g-2 data limits on mass and couplings of  $e^*$  and  $\mu^*$ . See figures 2 and 3 of the paper.

NODE=S054EXS;LINKAGE=B

NODE=S054EXS;LINKAGE=CH

NODE=S054EXS;LINKAGE=AA

NODE=S054EXS;LINKAGE=AB

NODE=S054EXS;LINKAGE=AC

NODE=S054EXS;LINKAGE=CR

NODE=S054EXS;LINKAGE=GN

NODE=S054EXS;LINKAGE=KD

NODE=S054EXG NODE=S054EXG

NODE=S054EXG

NODE=S054EXG;LINKAGE=AB

NODE=S054EXI NODE=S054EXI

NODE=S054EXI

NODE=S054EXI;LINKAGE=DD

NODE=S054EXI;LINKAGE=H

NODE=S054EXI;LINKAGE=E

#### MASS LIMITS for Excited $\mu$ ( $\mu$ \*)

#### NODE=S054225

NODE=S054MXP

NODE=S054MXP

## Limits for Excited $\mu$ ( $\mu$ \*) from Pair Production

These limits are obtained from  $e^+e^- \to \mu^{*+}\mu^{*-}$  and thus rely only on the (electroweak) charge of  $\mu^*$ . Form factor effects are ignored unless noted. For the case of limits from Z decay, the  $\mu^*$  coupling is assumed to be of sequential type. All limits assume a dominant  $\mu^* \to \mu \gamma$  decay except the limits from  $\Gamma(Z)$ .

For limits prior to 1987, see our 1992 edition (Physical Review D45 S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>103.2	95	<sup>50</sup> ABBIENDI	02G	OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
• • • We d	o not use	the following data	for a	verages.	fits, limits, etc. • • •

>102.8 95 51 ACHARD 03B L3  $e^+e^- \rightarrow \mu^*\mu^*$  Homodoublet type

# NODE=S054MXP

NODE=S054MXP;LINKAGE=GN NODE=S054MXP;LINKAGE=CR

#### NODE=S054MXS NODE=S054MXS

# Limits for Excited $\mu$ ( $\mu^*$ ) from Single Production

These limits are from  $e^+e^- \to \mu^*\mu$  and depend on transition magnetic coupling between  $\mu$  and  $\mu^*$ . All limits assume  $\mu^* \to \mu\gamma$  decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling,  $\eta_L = \eta_R = 1$ . In most papers, the limit is expressed in the form of an excluded region in the  $\lambda - m_{\mu^*}$  plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review **D45** S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 1.750 × 10 <sup>3</sup> (CL =	= 95%)	$[>1.090 \times 10^3 \text{ GeV} (C)]$	L = 95%	) OUR 2012 BEST
>1750	95	<sup>52</sup> AAD 12A	z ATLS	$pp \rightarrow \mu^{(*)}\mu^*X$

• • • We do not use the following data for averages, fits, limits, etc. • •

```
<sup>53</sup> CHATRCHYAN 11x CMS
>1090
                                             <sup>54</sup> ABAZOV
                                                                      06E D0
                                                                                          p\overline{p} \rightarrow \mu\mu^*
                                             <sup>55</sup> ABULENCIA,A 06B CDF
> 221
                                  95
                                                                                         p\overline{p} \rightarrow \mu\mu^*, \mu^* \rightarrow \mu\gamma
                                             <sup>56</sup> ACHARD
> 180
                                  95
                                                                      03B L3
                                             <sup>57</sup> ABBIENDI
                                                                      02G OPAL e^+e^- \rightarrow \mu \mu^*
> 190
```

 $^{52}$  AAD 12AZ search for  $\mu^*$  production via four-fermion contact interaction in pp collisions with  $\mu^*\to~\mu\gamma$  decay. The quoted limit assumes  $\varLambda=m_{\mu^*}$ . See their Fig. 8 for the exclusion plot in the mass-coupling plane.

<sup>53</sup>CHATRCHYAN 11X search for single  $\mu^*$  production in pp collisions with the decay  $\mu^* \to \mu \gamma$ .  $f = f' = \Lambda/m_{\mu^*}$  is assumed. See their Fig. 2 for the exclusion plot in the mass-coupling plane.

 $^{54}$  ABAZOV  $^{06}$  assume  $~\mu\mu^*~$  production via four-fermion contact interaction  $(4\pi/\Lambda^2)(\overline{q}_L\gamma^\mu q_L)(\overline{\mu}_L^*\gamma_\mu\mu).$  The obtained limit is  $m_{\mu^*}>$  618 GeV ( $m_{\mu^*}>$  688 GeV) for  $\Lambda=1$  TeV ( $\Lambda=m_{\mu^*}$ ).

 $^{55}f=f'=\Lambda/m_{\mu^*}$  is assumed for the  $\mu^*$  coupling. See their Fig.4 for the exclusion limit in the mass-coupling plane. ABULENCIA,A 06B also obtain  $m_{\mu^*}$  limit in the contact interaction model with  $\Lambda=m_{\mu^*},\,m_{\mu^*}>696$  GeV.

<sup>56</sup> ACHARD 03B result is from  $e^+e^-$  collisions at  $\sqrt{s}=189$ –209 GeV.  $f=f'=\Lambda/m_{\mu^*}$  is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

<sup>57</sup> ABBIENDI 02G result is from  $e^+e^-$  collisions at  $\sqrt{s}=183$ –209 GeV.  $f=f'=\Lambda/m_{\mu^*}$  is assumed for  $\mu^*$  coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane.

## NODE=S054MXS

NODE=S054MXS;LINKAGE=A

NODE=S054MXS;LINKAGE=CH

NODE=S054MXS;LINKAGE=VO

NODE=S054MXS;LINKAGE=UL

NODE=S054MXS;LINKAGE=CR

NODE=S054MXS;LINKAGE=GN

#### Indirect Limits for Excited $\mu$ ( $\mu$ \*)

These limits make use of loop effects involving  $\mu^*$  and are therefore subject to theoretical uncertainty.

 VALUE (GeV)
 DOCUMENT ID
 TECN
 COMMENT

 • • • We do not use the following data for averages, fits, limits, etc. • •

<sup>58</sup> RENARD 82 THEO g-2 of muon

 $^{58}$  RENARD 82 derived from g-2 data limits on mass and couplings of  $e^*$  and  $\mu^*.$  See figures 2 and 3 of the paper.

NODE=S054MXI

NODE=S054MXI

NODE=S054MXI

NODE=S054MXI;LINKAGE=O

<sup>&</sup>lt;sup>50</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=183$ –209 GeV. f=f' is assumed.

 $<sup>^{51}</sup>$  From e $^+$ e $^-$  collisions at  $\sqrt{s}=189$ –209 GeV. f=f' is assumed. ACHARD 03B also obtain limit for  $f=-f'\colon m_{\mu^*}>96.6$  GeV.

#### MASS LIMITS for Excited $\tau$ ( $\tau^*$ )

#### NODE=S054230

NODE=S054TXP

NODE=S054TXP

NODE=S054TXP

#### Limits for Excited $\tau$ ( $\tau^*$ ) from Pair Production

These limits are obtained from  $e^+e^- \to \tau^{*+}\tau^{*-}$  and thus rely only on the (electroweak) charge of  $\tau^*$ . Form factor effects are ignored unless noted. For the case of limits from Z decay, the  $\tau^*$  coupling is assumed to be of sequential type. All limits assume a dominant  $\tau^* \to \tau \gamma$  decay except the limits from  $\Gamma(Z)$ .

For limits prior to 1987, see our 1992 edition (Physical Review D45 S1 (1992)).

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>103.2	95	<sup>59</sup> ABBIENDI	<b>02</b> G	OPAL	$e^+e^-  ightarrow \  au^* au^*$ Homodoublet type
• • • We d	lo not us	e the following data	for a	verages	fits limits etc • • •

>102.8 95  $^{60}$  ACHARD 03B L3  $e^+e^ightarrow au^* au^*$  Homodoublet type

<sup>59</sup> From  $e^+e^-$  collisions at  $\sqrt{s}=183$ –209 GeV. f=f' is assumed.

 $^{60}$  From  $e^+\,e^-$  collisions at  $\sqrt{s}=$  189–209 GeV. f=f' is assumed. ACHARD 03B also obtain limit for  $f=-f'\colon$   $m_{\tau^*}>$  96.6 GeV.

# Limits for Excited $\tau$ ( $\tau^*$ ) from Single Production

These limits are from  $e^+e^- \to \tau^*\tau$  and depend on transition magnetic coupling between  $\tau$  and  $\tau^*$ . All limits assume  $\tau^* \to \tau\gamma$  decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling,  $\eta_L = \eta_R = 1$ . In most papers, the limit is expressed in the form of an excluded region in the  $\lambda - m_{\tau^*}$  plane. See the original papers.

VALUE (GeV)CL%DOCUMENT IDTECNCOMMENT>1859561 ABBIENDI02GOPAL $e^+e^- \rightarrow \tau \tau^*$ • • • We do not use the following data for averages, fits, limits, etc. • • •

>180 95  $^{62}$  ACHARD 03B L3  $\mathrm{e^+e^-} \rightarrow \tau \tau^*$ 

61 ABBIENDI 02G result is from  $e^+e^-$  collisions at  $\sqrt{s}=183$ –209 GeV.  $f=f'=\Lambda/m_{\tau^*}$  is assumed for  $\tau^*$  coupling. See their Fig. 4c for the exclusion limit in the mass-coupling plane

<sup>62</sup> ACHARD 03B result is from  $e^+e^-$  collisions at  $\sqrt{s}=189$ –209 GeV.  $f=f'=\Lambda/m_{\tau^*}$  is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

NODE=S054TXP:LINKAGE=GN

NODE=S054TXP;LINKAGE=CR

NODE=S054TXS NODE=S054TXS

NODE=S054TXS

NODE=S054TXS;LINKAGE=GN

NODE=S054TXS;LINKAGE=CR

## MASS LIMITS for Excited Neutrino ( $\nu^*$ )

#### Limits for Excited $\nu$ ( $\nu^*$ ) from Pair Production

These limits are obtained from  $e^+e^- \to \nu^*\nu^*$  and thus rely only on the (electroweak) charge of  $\nu^*$ . Form factor effects are ignored unless noted. The  $\nu^*$  coupling is assumed to be of sequential type unless otherwise noted. All limits assume a dominant  $\nu^* \to \nu \gamma$  decay except the limits from  $\Gamma(Z)$ .

 VALUE (GeV)
 CL%
 DOCUMENT ID
 TECN
 COMMENT

 >102.6
 95
 63 ACHARD
 03B
 L3
  $e^+e^- \rightarrow \nu^*\nu^*$  Homodoublet type

 • • • We do not use the following data for averages, fits, limits, etc. • • •

64 ABBIENDI 04N OPAL

 $^{63}$  From  $e^+\,e^-$  collisions at  $\sqrt{s}=189$ –209 GeV. f=-f' is assumed. ACHARD 03B also obtain limit for  $f=f'\colon m_{\nu_e^*}>101.7$  GeV,  $m_{\nu_\mu^*}>101.8$  GeV, and  $m_{\nu_\tau^*}>92.9$  GeV.

See their Fig. 4 for the exclusion plot in the mass-coupling plane.

 $^{64}$  From  $\,{\rm e^+\,e^-}\,$  collisions at  $\sqrt{s}=192$ –209 GeV, ABBIENDI 04N obtain limit on  $\sigma({\rm e^+\,e^-}\to~\nu^*\nu^*)~{\rm B^2}(\nu^*\to~\nu\gamma).$  See their Fig.2. The limit ranges from 20 to 45fb for  $m_{\nu^*}^{}>$  45 GeV.

#### NODE=S054233

NODE=S054EXN NODE=S054EXN

NODE=S054EXN

NODE=S054EXN;LINKAGE=CR

NODE=S054EXN;LINKAGE=AB

#### Limits for Excited $\nu$ ( $\nu^*$ ) from Single Production

These limits are from  $e^+e^- \to \nu\nu^*$ ,  $Z \to \nu\nu^*$ , or  $ep \to \nu^*X$  and depend on transition magnetic coupling between  $\nu/e$  and  $\nu^*$ . Assumptions about  $\nu^*$  decay mode are given in footnotes.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>213	95	<sup>65</sup> AARON	80	H1	$ep \rightarrow \nu^* X$
• • • We do	not use	the following data	for a	verages,	fits, limits, etc. • • •
>190	95	<sup>66</sup> ACHARD	<b>03</b> B	L3	$\mathrm{e^+e^-}  ightarrow \  u   u^*$
none 50-150	95	<sup>67</sup> ADLOFF	02	H1	$ep \rightarrow \nu^* X$
>158	95	<sup>68</sup> CHEKANOV	<b>02</b> D	ZEUS	$ep \rightarrow \nu^* X$
>171	95	<sup>69</sup> ACCIARRI	<b>01</b> D	L3	$e^+e^-  ightarrow  u  u^*$

NODE=S054EXO NODE=S054EXO

NODE=S054EXO

<sup>65</sup> AARON 08 search for single  $\nu^*$  production in ep collisions with the decays  $\nu^* \to \nu \gamma$ ,  $\nu Z$ , eW. The quoted limit assumes  $f = -f' = \Lambda/m_{\nu^*}$ . See their Fig. 3 and Fig. 4 for the exclusion plots in the mass-coupling plane.

 $^{66}$  ACHARD 03B result is from  ${\rm e^+\,e^-}$  collisions at  $\sqrt{s}=189$ –209 GeV. The quoted limit is for  $\nu_e^*.~f=-f'=\Lambda/m_{\nu^*}$  is assumed. See their Fig. 4 for the exclusion plot in the mass-coupling plane.

<sup>67</sup> ADLOFF 02 search for single  $\nu^*$  production in ep collisions with the decays  $\nu^* \to \nu \gamma$ ,  $\nu Z$ , eW. The quoted limit assumes  $f = -f' = \Lambda/m_{\nu^*}$ . See their Fig. 1 for the exclusion plots in the mass-coupling plane.

<sup>68</sup> CHEKANOV 02D search for single  $\nu^*$  production in ep collisions with the decays  $\nu^* \rightarrow \nu \gamma$ ,  $\nu Z$ , eW.  $f = -f' = \Lambda/m_{\nu^*}$  is assumed for the  $e^*$  coupling. CHEKANOV 02D also obtain limit for  $f = f' = \Lambda/m_{\nu^*}$ :  $m_{\nu^*} >$ 135 GeV. See their Fig. 5c and Fig. 5d for the exclusion plot in the mass-coupling plane.

<sup>69</sup> ACCIARRI 01D search for  $\nu\nu^*$  production in  $e^+e^-$  collisions at  $\sqrt{s}=192$ –202 GeV with decays  $\nu^* \to \nu\gamma$ ,  $\nu^* \to eW$ .  $f=-f'=\Lambda/m_{\nu^*}$  is assumed for the  $\nu^*$  coupling. See their Fig. 4 for limits in the mass-coupling plane.

#### NODE=S054EXO;LINKAGE=AA

NODE=S054EXO;LINKAGE=CR

NODE=S054EXO;LINKAGE=LF

NODE=S054EXO;LINKAGE=KD

NODE=S054EXO;LINKAGE=XK

## MASS LIMITS for Excited $q(q^*)$

#### Limits for Excited $q(q^*)$ from Pair Production

These limits are mostly obtained from  $e^+e^-\to q^*\overline{q}^*$  and thus rely only on the (electroweak) charge of the  $q^*$ . Form factor effects are ignored unless noted. Assumptions about the  $q^*$  decay are given in the comments and footnotes.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>338	95	<sup>70</sup> AALTONEN	10H	CDF	$q^* \rightarrow tW^-$
ullet $ullet$ $ullet$ We do not use	the follow	ing data for average	es, fits	s, limits,	etc. • • •
		<sup>71</sup> BARATE	<b>98</b> U	ALEP	$Z \rightarrow q^* q^*$
> 45.6	95	<sup>72</sup> ADRIANI	93м	L3	$u$ or $d$ type, $Z \rightarrow q^* q^*$
> 41.7	95	<sup>73</sup> BARDADIN			
> 44.7	95	<sup>73</sup> BARDADIN	92	RVUE	$d$ -type, $\Gamma(Z)$
> 40.6	95	<sup>74</sup> DECAMP	92	ALEP	$u$ -type, $\Gamma(Z)$
> 44.2	95	-	92	ALEP	$d$ -type, $\Gamma(Z)$
> 45	95	<sup>75</sup> DECAMP	92	ALEP	$u$ or $d$ type, $Z  o q^* q^*$
> 45	95	<sup>74</sup> ABREU	91F	DLPH	$u$ -type, $\Gamma(Z)$
> 45	95	<sup>74</sup> ABREU	91F	DLPH	<i>d</i> -type, $\Gamma(Z)$

<sup>&</sup>lt;sup>70</sup> AALTONEN 10H obtain limits on the  $q^* q^*$  production cross section in  $p\overline{p}$  collisions. See their Fig. 3.

#### Limits for Excited $q(q^*)$ from Single Production

These limits are from  $e^+e^- \to q^*\overline{q}$ ,  $p\overline{p} \to q^*X$ , or  $pp \to q^*X$  and depend on transition magnetic couplings between q and  $q^*$ . Assumptions about  $q^*$  decay mode are given in the footnotes and comments.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT	
> 3.320 x 10 <sup>3</sup> LIMIT]	(CL = 9	<b>)5%)</b> [>2.490 × 1	10 <sup>3</sup> G	eV (CL	= 95%) OUR 2012 BEST	
>3320	95	<sup>76</sup> CHATRCHYAN	I 13A	CMS	$pp \rightarrow q^* X, q^* \rightarrow qg$	
• • • We do not i	use the f	ollowing data for a	verage	s, fits, li	mits, etc. • • •	
>2460	95	<sup>77</sup> AAD	12AO	ATLS	$pp \rightarrow q^* X, q^* \rightarrow q \gamma$	ı
>2990	95	<sup>78</sup> AAD	<b>12</b> S	ATLS	$pp \rightarrow q^*X$ , $q^* \rightarrow qg$	
					$p\overline{p} \rightarrow q^*X, q^* \rightarrow qZ, qW$	
>2490	95		111Y	CMS	$pp \rightarrow q^*X$ , $q^* \rightarrow qg$	
none 300-1260	95	<sup>81</sup> AAD	-	ATLS	$pp \rightarrow q^*X, q^* \rightarrow qg$	
none 500-1580	95	<sup>81</sup> KHACHATRY.	10	CMS	$pp \rightarrow q^*X, q^* \rightarrow qg$	
> 510	95		06F	D0	$p\overline{p} \rightarrow q^*X, q^* \rightarrow qZ$	
> 775	95	<sup>83</sup> ABAZOV	04C	D0	$p\overline{p} \rightarrow q^*X, q^* \rightarrow qg$	

NODE=S054235

NODE=S054EQP NODE=S054EQP

NODE=S054EQP

OCCUR=2 OCCUR=3 OCCUR=4 OCCUR=5

OCCUR=2

NODE=S054EQP;LINKAGE=AA

NODE=S054EQP;LINKAGE=BU

NODE=S054EQP;LINKAGE=E NODE=S054EQP;LINKAGE=BO NODE=S054EQP;LINKAGE=I NODE=S054EQP;LINKAGE=J

NODE=S054EQS NODE=S054EQS

NODE=S054EQS

<sup>71</sup> BARATE 98U obtain limits on the form factor. See their Fig. 16 for limits in mass-form factor plane.

 $<sup>^{72}</sup>$  ADRIANI 93M limit is valid for B( $q^* o qg$ )> 0.25 (0.17) for up (down) type.

 $<sup>^{73}</sup>$ BARDADIN-OTWINOWSKA 92 limit based on  $\Delta\Gamma(Z)$ <36 MeV.

<sup>&</sup>lt;sup>74</sup> These limits are independent of decay modes.

<sup>&</sup>lt;sup>75</sup> Limit is for B( $q^* \rightarrow qg$ )+B( $q^* \rightarrow q\gamma$ )=1.

 $^{76}\,\mathrm{CHATRCHYAN}$  13A assume  $\varLambda=m_{q^*}$  .

 $^{77}\,\mathrm{AAD}$  12AO assume  $\varLambda=m_{q^*}$  ,  $f_{\mathrm{S}}=\overset{\cdot}{f}=f'=1.$ 

 $^{78}$  AAD 12S assume  $\Lambda=m_{a^*}$ .

<sup>79</sup> ABAZOV 11F search for vectorlike quarks decaying to W+jet and Z+jet in  $p\overline{p}$  collisions. See their Fig. 3 and Fig. 4 for the limits on  $\sigma \cdot B$ .

<sup>80</sup> CHATRCHYAN 11Y assume degenerate  $q^*$  with  $f_s = \Lambda/m_{q^*}$ .

<sup>81</sup> AAD 10, KHACHATRYAN 10 search for heavy resonance decaying to 2 jets in pp collisions at  $\sqrt{s}=7$  TeV.  $f_{\rm S}=f=f'=1$  is assumed.

 $^{82}$  ABAZOV 06F assume  $q^*$  production via qg fusion and via contact interactions. The quoted limit is for  $\Lambda=m_{q^*}$ 

<sup>83</sup> ABAZOV 04C assume  $f_s = f = f' = \Lambda/m_{a^*}$ .

NODE=S054EQS;LINKAGE=F

NODE=S054EQS;LINKAGE=G

NODE=S054EQS;LINKAGE=A NODE=S054EQS;LINKAGE=AZ

NODE=S054EQS;LINKAGE=CH

NODE=S054EQS;LINKAGE=AA

NODE=S054EQS;LINKAGE=VO

NODE=S054EQS;LINKAGE=AB

# MASS LIMITS for Color Sextet Quarks $(q_6)$

VALUE (GeV)CL%DOCUMENT IDTECNCOMMENT>849584 ABE89DCDF $p\overline{p} \rightarrow q_6 \overline{q}_6$ 

84 ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color sextet quark is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. A limit of 121 GeV is obtained for a color decuplet. NODE=S054CQ NODE=S054CQ

NODE=S054CQ;LINKAGE=A

## MASS LIMITS for Color Octet Charged Leptons ( $\ell_8$ )

 $\lambda \equiv m_{\ell_8}/\Lambda$   $\frac{\text{VALUE (GeV)}}{\text{>86}} \qquad \frac{\text{CL\%}}{95} \qquad \frac{\text{DOCUMENT ID}}{\text{ABE}} \qquad \frac{\text{TECN}}{\text{Stable } \ell_8 : \ p\overline{p} \rightarrow \ \ell_8\overline{\ell}_8}$ 

 $\bullet$   $\bullet$  We do not use the following data for averages, fits, limits, etc.  $\bullet$   $\bullet$ 

86 ABT 93 H1  $e_8: e_p \to e_8 X$ 

85 ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color octet lepton is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. The limit improves to 99 GeV if it always fragments into a unit-charged hadron.

 $^{86}$  ABT 93 search for  $e_8$  production via e-gluon fusion in ep collisions with  $e_8\to eg$ . See their Fig. 3 for exclusion plot in the  $m_{e_8}$ – $\Lambda$  plane for  $m_{e_8}=$  35–220 GeV.

NODE=S054CL

NODE=S054CL NODE=S054CL

NODE=S054CL;LINKAGE=AC

NODE=S054CL;LINKAGE=G2

#### MASS LIMITS for Color Octet Neutrinos ( $\nu_8$ )

• • • We do not use the following data for averages, fits, limits, etc. • •

none 3.8–29.8 95 88 KIM 90 AMY  $\nu_8$ :  $e^+e^- \to$  acoplanar jets none 9–21.9 95 89 BARTEL 87B JADE  $\nu_8$ :  $e^+e^- \to$  acoplanar jets

 $^{87}$  BARGER 89 used ABE 89B limit for events with large missing transverse momentum. Two-body decay  $\nu_{8} \rightarrow \ \nu_{g}$  is assumed.

 $^{88}\,\mathrm{KIM}$  90 is at  $E_\mathrm{cm}=$  50–60.8 GeV. The same assumptions as in BARTEL 87B are used.

 $^{89}$  BARTEL 87B is at  $E_{\rm cm}=46.3$ –46.78 GeV. The limit assumes the  $\nu_8$  pair production cross section to be eight times larger than that of the corresponding heavy neutrino pair production. This assumption is not valid in general for the weak couplings, and the limit can be sensitive to its  ${\rm SU(2)}_L\times{\rm U(1)}_Y$  quantum numbers.

NODE=S054CN

NODE=S054CN NODE=S054CN

OCCUR=3

NODE=S054CN;LINKAGE=C

NODE=S054CN;LINKAGE=D NODE=S054CN;LINKAGE=A

# MASS LIMITS for $W_8$ (Color Octet W Boson)

VALUE (GeV) DOCUMENT ID TECN COMMENT

• • • We do not use the following data for averages, fits, limits, etc. • • •

 $^{90}$  ALBAJAR 89 UA1  $p\overline{p} \rightarrow W_8$  X,  $W_8 \rightarrow W_8$ 

 $^{90}$  ALBAJAR 89 give  $\sigma(W_8 \to~W+{\rm jet})/\sigma(W) <$  0.019 (90% CL) for  $m_{\slash\hspace{-0.4em}W_8}~>$  220 GeV.

NODE=S054CW NODE=S054CW

NODE=S054CW;LINKAGE=A

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ABDALLAH  O4N  CHARD  O3B  PL  B668  PL  B658  PL  B658  B67  PA  Chard  O3B  PL  B658  PL  B658  PL  B686  B67  PA  Chard  O3B  PL  B658  PL  B658  PL  B686  B67  AA  ABabich et al.  (L3 Collab.)  REFID=49521  REFID=49521  REFID=49461  REFID=49461  REFID=49461  REFID=49461  REFID=49461  REFID=48466  ABBIENDI  O2C  PL  B531  B7  Chard  Chexnov  Chexnov	ABBIENDI	04G	EPJ C33 173	G. Abbiendi et al.	(OPAL Collab.)	REFID=49915
ABDALLAH  O4N  CHARD  O3B  PL  B568  CH  D3B  PL  B568  CH  BBICH  O3C  D3B  D4  D568  D3C  D4  D569  D3C  D569  D3C  D569  D5	ABBIENDI	04N	PL B602 167	G. Abbiendi et al.	(OPAL Collab.)	REFID=50288
ACHARD 03B PL 8568 23 P. Achard et al.  ABBIENDI 03 EPJ C29 103 A.A. Babich et al.  ABBIENDI 02G PL 8541 57 G. Abbiendi et al.  ACHARD 02D PL 8531 28 P. Achard et al.  ACHARD 02D PL 8531 28 P. Achard et al.  ACHARD 02D PL 8531 28 P. Achard et al.  ACHARD 02D PL 8532 9 C. Adloff et al.  (L3 Collab.) REFID=48917  ACHARD 02D PL 8539 32 S. Chekanov et al.  (L3 Collab.) REFID=48826  CHEKANOV 02D PL 8593 32 S. Chekanov et al.  (CEUS Collab.) REFID=48928  AFFOLDER  01D PL 8502 37 M. Acciarri et al.  (L3 Collab.) REFID=48908  AFFOLDER  01D PR 187 231803 T. Affolder et al.  (CDF Collab.) REFID=48368  CHEUNG 01B PL 8517 167 K. Cheung  AREFID=48289  ARREU 005 PL 8489 45 P. Abreu et al.  (CL3 Collab.) REFID=48289  ARREU 005 PL 8489 41 M. Acciarri et al.  (L3 Collab.) REFID=48289  ARREU 005 PL 8489 41 M. Acciarri et al.  (L3 Collab.) REFID=47715  AFFOLDER  010 PR D62 012004 T. Affolder et al.  (CDF Collab.) REFID=47757  AFFOLDER  010 PR D62 012004 T. Affolder et al.  (CDF Collab.) REFID=47757  AFFOLDER  010 PR D62 012004 T. Affolder et al.  (CDF Collab.) REFID=47763  AFFOLDER  010 PR D62 012004 T. Affolder et al.  (CDF Collab.) REFID=47653  MCFARLAND 98  EPJ C1 509 K.S. McFarland et al.  (CDF Collab.) REFID=48104  REFID=48289  ALEFID=48289  ALEFID=48289  ALEFID=48289  ALEFID=48368		04N		J. Abdallah et al.		
BABICH   03	ACHARD	03B	PL B568 23	P. Achard et al.	` (L3 Collab.)	REFID=49521
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CHEKANOV   OZD   PL   B549   32   S. Chekanov et al.   (ZÈUS Collab.)   REFID=49089						
ACCIARRI 01D PL B502 37 M. Acciarri et al. (L3 Collab.) REFID=48096 AFFOLDER 011 PR L87 231803 T. Affolder et al. (CDF Collab.) REFID=48368 REFID=48368 PR D04 071701 D. Bourilkov REFID=48368 REFID=48368 REFID=48368 REFID=48368 REFID=48368 REFID=48269 RBREU 005 PL B485 45 P. Abreu et al. (DELPHI Collab.) REFID=47757 AFFOLDER 001 PR D62 012004 T. Affolder et al. (L3 Collab.) REFID=47757 AFFOLDER 001 PR D62 012004 T. Affolder et al. (CDF Collab.) REFID=47663 BARATE 98U EPJ C4 571 R. Barate et al. (ALEPH Collab.) REFID=48663 MCFARLAND 98 PR D57 391 V. Barger et al. (ALEPH Collab.) REFID=48063 MCFARLAND 98 EPJ C1 509 K.S. McFarland et al. (CCFR/NuTeV Collab.) REFID=46140 ABE 97T PRL 79 2198 F. Abe et al. (CDF Collab.) REFID=4596 DIAZCRUZ 94 PR D49 R2149 J.L. Diaz Cruz, O.A. Sampayo (CINV) REFID=43371 ADRIANI 93M PRPL 236 1 O. Adriani et al. (L3 Collab.) REFID=43731 ADRIANI 93M PRPL 236 1 O. Adriani et al. (L3 Collab.) REFID=437404 ABRDDAIN 92 ZPHY C55 163 M. Bardadin-Otwinowska (CLER) REFID=42109 DECAMP 92 PR D45 S1 K. Hikasa et al. (ALEPH Collab.) REFID=41877 PDG 92 PR D45 S1 K. Hikasa et al. (ALEPH Collab.) REFID=41870 ABREU 91F NP B367 511 P. Abreu et al. (EMCMY Collab.) REFID=41840 ABRABADIN 92 PRPL 216 253 D. Decamp et al. (ALEPH Collab.) REFID=41840 ABREU 91F NP B367 511 P. Abreu et al. (EMCMY Collab.) REFID=41840 ABREU 91F NP B367 511 P. Abreu et al. (EMCMY Collab.) REFID=41840 ABREU 91F NP B367 511 P. Abreu et al. (EMCMY Collab.) REFID=41840 ABREU 91F NP B367 511 P. Abreu et al. (CDF Collab.) REFID=41090 ABREU 91F NP B367 511 P. Abreu et al. (CDF Collab.) REFID=41084 ABB 89D PRL 62 1825 F. Abe et al. (CDF Collab.) REFID=41079 ABE 89D PRL 63 1447 F. Abe et al. (CDF Collab.) REFID=41079 ABE 89D PRL 63 1447 F. Abe et al. (CDF Collab.) REFID=41079 ABE 89D PRL 63 1447 F. Abe et al. (CDF Collab.) REFID=41055 GRIFOLS 86 PL 1688 264 J. A. Grifols, S. Peris (BARC) REFID=41055 GRIFOLS 86 PL 1688 264 J. A. Grifols, S. Peris (BARC) REFID=4104055 REFID=4104067 Also (PR) 327 (erratum) P. A. Jodidio et al. (LBL, NW						
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